

PLATE FOR FORMING METAL WIRES AND METHOD OF FORMING METAL WIRES USING THE SAME

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BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to plate for forming metal wires and method of forming the metal wires using the same, and more particularly, to a
10 plate for forming metal wires and method of forming the metal wires using the same, in which insulating film patterns of a multi-layer structure are shaped by a single process using a plate in which engraved patterns of wire shapes to be formed are formed and in which the metal wires are formed in trenches and via holes formed in the insulating film patterns by means of the damascene
15 process.

Background of the Related Art

A conventional method of forming metal wires in the semiconductor device will be now described by reference to FIG. 1A ~ FIG. 1D.

20 Referring to FIG. 1A, a bottom low-dielectric insulating film **102** is formed on a silicon substrate **101** for which a given process is implemented. An anti-polishing layer **103** is then formed on the bottom low-dielectric insulating film **102**. Next, the anti-polishing layer **103** and the bottom low-dielectric insulating film **102** are patterned to form a trench of a given depth.

Thereafter, an anti-diffusion film **104** and a copper film **105** are sequentially formed on the entire structure. The copper film **105** and the anti-diffusion film **104** formed on the anti-polishing layer **103** are then removed by means of a chemical mechanical polishing (CMP) process, so copper wires **105** surrounded by the anti-diffusion film **104** are formed within the trench.

By reference to FIG. 1B, top low-dielectric insulating films **106a ~ 106e** of a multi-layer structure are sequentially formed on the entire structure. A mask pattern for forming a via hole **107** is then formed on the top low-dielectric insulating film **106e**. Next, the top low-dielectric insulating films **106e ~ 106b** are etched by a given depth by means of an etch process using the mask pattern **107** as an etch mask, thus forming a via hole **108**. At this time, the top low-dielectric insulating film **106a** is used as an etch stop layer.

With reference to FIG. 1C, after the mask pattern **107** is removed, a mask pattern **109** for forming the trench is formed on the top low-dielectric insulating film **106e**. The top low-dielectric insulating films **106e** and **106d** are then etched by means of an etch process using the mask pattern **109** as an etch mask, thereby forming a trench **110**. At the same time, remaining top low-dielectric insulating film **106a** is etched to complete the via hole **108** so that the copper wires **105** are exposed. At this time, the top low-dielectric insulating film **106c** is used as the etch stop layer.

Referring to FIG. 1D, an anti-diffusion film **111** and a copper film **112** are sequentially formed on the entire structure including the trench **110** and the via hole **108**. The copper film **112** and the anti-diffusion film **111** deposited on the top low-dielectric insulating film **106e** are then removed by means of a

chemical mechanical polishing (CMP) process, so that copper wires 112 surrounded by the anti-diffusion film 111 is formed within the trench. The copper wires 112 are connected to the copper wires 105 via the via hole 108.

In the conventional method of forming the metal wires of a multi-layer structure using the damascene process, however, there occur several problems due to diffused reflection, flatness of the surface, etc., which are caused by the underlying copper wires during the photolithography process for forming the via hole or the trench. For this reason, there is lots of difficulty in forming a pattern of an ultra-fine size. Furthermore, during the etch process, as the low-dielectric insulating film is lost or the pattern is crumpled, fail is caused. Due to this, in order to form wires of a multi-layer structure, multi-step photolithography and etch processes must be implemented.

SUMMARY OF THE INVENTION

Accordingly, the present invention is contrived to substantially obviate one or more problems due to limitations and disadvantages of the related art.

An object of the present invention is to provide a plate for forming metal wires and method of forming the metal wires using the same, in which an insulating film pattern is shaped by a single process using a plate in which engraved patterns of wire shapes are formed.

Another object of the present invention is to provide a plate for forming metal wires and method of forming the metal wires using the same, in which insulating film patterns of a multi-layer structure are shaped using a plate in which engraved patterns of wire shapes are formed.

Additional advantages, objects, and features of the invention will be set forth in part in the description which follows and in part will become apparent to those having ordinary skill in the art upon examination of the following or may be learned from practice of the invention. The objectives and other
5 advantages of the invention may be realized and attained by the structure particularly pointed out in the written description and claims hereof as well as the appended drawings.

To achieve these objects and other advantages and in accordance with the purpose of the invention, as embodied and broadly described herein, a plate
10 for forming metal wires according to one embodiment of the present invention is characterized in that it comprises a plate in which a plurality of implantation holes are formed and a sidewall of a given height is formed at its edge, an engraved pattern for forming a plurality of trenches formed on the plate, and an engraved pattern for forming a plurality of via holes formed on the
15 engraved pattern for forming the trenches.

In another embodiment of the present invention, a plate for forming metal wires is characterized in that it comprises a plate in which a plurality of first and second implantation holes are each formed and a sidewall of a given height is formed at its edge, an engraved pattern for forming a plurality of
20 trenches formed on the plate, and an engraved pattern for forming a plurality of via holes formed on the engraved pattern for forming the trenches.

A method of forming metal wires using a plate according to one embodiment of the present invention is characterized in that it comprises the steps of a) forming a low-dielectric insulating film on a silicon substrate for

which given processes are implemented, and then forming a trench in the low-dielectric insulating film; b) forming lower metal wires within the trench; c) adhering a plate having a plate in which a plurality of implantation holes are formed and a sidewall of a given height is formed at its edge, an engraved pattern for forming a plurality of trenches formed on the plate, and an engraved pattern for forming a plurality of via holes formed on the engraved pattern for forming the trench, onto a silicon substrate; d) implanting a low-dielectric insulating material through the implantation holes and then annealing the low-dielectric insulating material; e) removing the plate to obtain a low-dielectric insulating film pattern having the plurality of the trenches shaped by the engraved pattern for forming the trenches and the plurality of the via holes shaped by the engraved pattern for forming the via holes; and f) forming upper metal wires, which are connected to the lower metal wires through the via holes, within the trenches.

15 In another embodiment of the present invention, a method of forming metal wires using a plate is characterized in that it comprises the steps of a) forming a low-dielectric insulating film on a silicon substrate for which given processes are implemented and then forming a trench in the low-dielectric insulating film; b) forming lower metal wires within the trench; c) adhering a plate having a plate in which a plurality of first and second implantation holes are each formed and a sidewall of a given height is formed at its edge, an engraved pattern for forming a plurality of trenches formed on the plate, and an engraved pattern for forming a plurality of via holes formed on the engraved pattern for forming the trench, onto a silicon substrate; d) implanting

a first insulating material of a given amount through the first implantation hole; e) implanting a second insulating material through the second implantation hole; f) removing the plate to obtain an insulating film pattern of a multi-layer structure having the plurality of the trenches shaped by the engraved pattern for forming the trenches and the plurality of the via holes shaped by the engraved pattern for forming the via holes; and g) forming upper metal wires, which are connected to the lower metal wires through the via holes, within the trenches.

In another aspect of the present invention, it is to be understood that both the foregoing general description and the following detailed description of the present invention are exemplary and explanatory and are intended to provide further explanation of the invention as claimed.

BRIEF DESCRIPTION OF THE DRAWINGS

The above and other objects, features and advantages of the present invention will be apparent from the following detailed description of the preferred embodiments of the invention in conjunction with the accompanying drawings, in which:

FIG. 1A ~ FIG. 1D are cross-sectional views of semiconductor devices for explaining a conventional method of forming metal wires in the device;

FIG. 2 is a cross-sectional view of a semiconductor device for explaining a plate for forming metal wires according to one embodiment of the present invention;

FIG. 3A ~ FIG. 3E are cross-sectional views of semiconductor devices

for explaining a method of forming metal wires using a plate for forming the metal wires according to one embodiment of the present invention;

FIG. 4 is a cross-sectional view of a semiconductor device for explaining a plate for forming metal wires according to another embodiment of the present invention; and

FIG. 5A ~ FIG. 5F are cross-sectional views of semiconductor devices for explaining a method of forming metal wires using a plate for forming the metal wires according to another embodiment of the present invention;

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Reference will now be made in detail to the preferred embodiments of the present invention, examples of which are illustrated in the accompanying drawings.

FIG. 2 is a cross-sectional view of a semiconductor device for explaining a plate for forming metal wires according to one embodiment of the present invention.

The plate for forming the metal wires **20** comprises a circular plate **20a** in which a plurality of implantation holes **20c** are formed and a sidewall **20b** of a give height is formed at its edge, engraved patterns **21** for forming a plurality of trenches formed on the plate **20a**, and engraved patterns **22** for forming a plurality of via holes formed on the engraved patterns **21**.

The plate for forming the metal wires may be made of a metal having a good abrasion resistance and a high melting point such as Ti, Ta, W, etc., nitrogenous compound of a metal or ceramics such as Al_2O_3 , etc. The

engraved patterns **21** for forming the plurality of the trenches and the engraved patterns **22** for forming the plurality of the via holes may be formed by means of a photolithography process and an etch process or a damascene process. A reactive ion etching (RIE) method is used as the etch process.

5 FIG. 3A ~ FIG. 3E illustrate processes of forming the metal wires of the multi-layer structure using the plate for forming the metal wires according to one embodiment of the present invention as in FIG. 2.

Referring to FIG. 3A, a bottom low-dielectric insulating film **302** is formed on a silicon substrate **301** for which given processes are implemented.

10 An anti-polishing layer **303** is then formed on the bottom low-dielectric insulating film **302**. Next, the anti-polishing layer **303** and the bottom low-dielectric insulating film **302** are patterned to form fine trenches of a given depth. Thereafter, an anti-diffusion film **304** and a copper film **305** are sequentially formed on the entire structure. The copper film **305** and the anti-

15 diffusion film **304** deposited on the anti-polishing layer **303** are removed by means of a chemical mechanical polishing (CMP) process, thus forming a copper wires **305** surrounded by the anti-diffusion film **304** within the trench. Thereafter, an anti-diffusion film **306** is selectively formed on the surface of the copper wires **305**. At this time, the anti-diffusion film **306** serves to

20 prevent diffusion of copper (Cu) in a subsequent process to prevent contamination of the substrate or the equipment and also facilitates an electrical contact with the metal wires to be formed on the top.

With reference to FIG. 3B, the plate **20** constructed as in FIG. 2 is located on a silicon substrate **301**. A proper pressure is applied to the plate

20 so that the sidewall **20b** adheres closely to the edge of the silicon substrate **301**. Only when the plate **20** and the silicon substrate **301** are completely sealed, a complete contact between the metal wires is accomplished and outside leakage of the insulating film is prevented.

5 By reference to FIG. 3C, a low-dielectric insulating material **307** of a liquid state or a sol or gel state having a given viscosity is completely injected into the space through the implantation hole **20c**. The low-dielectric insulating material **307** injected into the space is then annealed for over 10seconds, for example 10seconds ~ 10minutes so that a solvent contained in
10 the low-dielectric insulating material **307** is removed and the film quality is made dense at the same time. At this time, it is required that the plate **20** and the silicon substrate **301** be kept at a temperature of 100 ~ 450°C. A material containing carbon or an organic or inorganic series material of a low density is used as the low-dielectric insulating material **307**. It is preferred that the
15 buried thickness is 3000 ~ 30000 Å.

Referring to FIG. 3D, if the plate **20** is separated from the silicon substrate **301**, a low-dielectric insulating film pattern **307a** having a plurality of trenches **308** shaped by the engraved patterns **21** for forming the plurality of the trenches formed in the plate **20**, and a plurality of via holes **309** shaped
20 by the engraved patterns **22** for forming the plurality of the via holes formed in the plate **20**.

By reference to FIG. 3E, an anti-diffusion film **310** and a copper film **311** are sequentially formed on the entire structure of the low-dielectric insulating film pattern **307a** including the trenches **308** and the via holes **309**.

The copper film **311** and the anti-diffusion film **310** deposited on the low-dielectric insulating film pattern **307a** are then removed by a chemical mechanical polishing (CMP) process, so that copper wires **311** surrounded by the anti-diffusion film **310** are formed within the trench **308**. At this time, the
5 copper wires **311** on the via hole **309** are electrically connected to the underlying copper wires **305** by means of the anti-diffusion film **310** and the copper film **311** buried in the via hole **309**. Thereafter, an anti-diffusion film **312** is selectively formed only on the surface of the copper wires **311**.

The anti-diffusion films **304** and **310** are formed in thickness of 0.5 ~
10 50 nm by depositing Ta, TaN, TiN, TiNSi, WN, WCN or an alloy of their combination by means of a physical vapor deposition (PVD), chemical vapor deposition (CVD) or atomic layer deposition (ALD) method.

The copper films **305** and **311** are formed by depositing copper (Cu) of 200 ~ 2000 nm in thickness by means of an electroplating, electroless plating
15 or chemical vapor deposition (CVD) method until the trench is completely buried.

The anti-diffusion films **306** and **312** formed on the surface of the copper wires **305** and **311** may be formed using a high melting point metal such as W, Ti, Ta, etc., or a compound such as Ni, Co, P, B, etc. The anti-
20 diffusion films **306** and **312** of 1 ~ 100 nm in thickness may be formed only on the surface of the copper wires **305** and **311** by implementing a selective electroless plating method, etc.

If the processes of FIG. 3B ~ FIG. 3E are repeatedly implemented, the metal wires of a desired multi-layer structure could be formed.

FIG. 4 is a cross-sectional view of a semiconductor device for explaining a plate for forming metal wires according to another embodiment of the present invention.

The plate for forming the metal wires **40** comprises a circular plate **40a** in which first and second implantation holes **40c** and **40d** are each formed and a sidewall **40b** of a give height is formed at its edge, engraved patterns **41** for forming a plurality of trenches formed on the plate **40a**, and engraved patterns **42** for forming a plurality of via holes formed on the engraved patterns **41**.

The plate for forming the metal wires may be made of a metal having elasticity corresponding to fine curves of the substrate located at the bottom and pressure applied from the top, a good abrasion resistance and a high melting point such as Ti, Ta, W, etc., nitride compound of the metal, or ceramics such as Al_2O_3 , etc. The first and second implantation holes **40c** and **40d** are formed with uniform distribution so that the insulating material could be buried in a uniform thickness and must be discriminated so that insulating materials of different kinds could be implanted, respectively. The engraved patterns **41** for forming the plurality of the trenches and the engraved patterns **42** for forming the plurality of the via holes may be formed by means of a photolithography process and an etch process or a damascene process. A reactive ion etching (RIE) method is used as the etch process.

FIG. 5A ~ FIG. 5F illustrate processes of forming the metal wires using the plate for forming the metal wires constructed as in FIG. 4 according to another embodiment of the present invention;

Referring to FIG. 5A, a bottom low-dielectric insulating film **502** is

formed on a silicon substrate **501** for which given processes are implemented. An anti-polishing layer **503** is then formed on the bottom low-dielectric insulating film **502**. Next, the anti-polishing layer **503** and the bottom low-dielectric insulating film **502** are patterned to form fine trenches of a given depth. Thereafter, an anti-diffusion film **504** and a copper film **505** are sequentially formed on the entire structure. The copper film **505** and the anti-diffusion film **504** deposited on the anti-polishing layer **503** are removed by means of a chemical mechanical polishing (CMP) process, thus forming a copper wires **505** surrounded by the anti-diffusion film **504** within the trench. Thereafter, an anti-diffusion film **506** is selectively formed on the surface of the copper wires **505**. At this time, the anti-diffusion film **506** serves to prevent diffusion of copper (Cu) in a subsequent process to prevent contamination of the substrate or the equipment and also facilitates an electrical contact with the metal wires to be formed on the top.

With reference to FIG. 5B, the plate **40** constructed in FIG. 4 is located on a silicon substrate **501**. A proper pressure is applied to the plate **40** so that the sidewall **40b** adheres closely to the edge of the silicon substrate **501**. Only when the plate **40** and the silicon substrate **501** are completely sealed, a complete contact between the metal wires is accomplished and outside leakage of the insulating film is prevented.

By reference to FIG. 5C, a low-dielectric insulating material **507a** of a liquid state or a sol or gel state having a given viscosity is injected by a given thickness through the first implantation hole **40c**. The low-dielectric insulating material **507a** is then annealed for over 10seconds, for example

10seconds ~ 10minutes under an inert gas atmosphere of over 1 atmospheric pressure so that a solvent contained in the low-dielectric insulating material **507a** is removed and the film quality is made dense at the same time. At this time, it is required that the plate **40** and the silicon substrate **501** be kept at a temperature of 100 ~ 450°C. A material containing carbon, or organic or inorganic series material of a low density is used as the low-dielectric insulating material **507a**. It is preferred that the buried thickness is 3000 ~ 30000 Å.

By reference to FIG. 5D, an anti-polishing layer material **507b** of a liquid state or a sol or gel state having a given viscosity is injected by a given thickness through the second implantation hole **40d**. The anti-polishing layer material **507b** is then annealed for over 10seconds, for example 10seconds ~ 10minutes under an inert gas atmosphere of over 1 atmospheric pressure so that a solvent contained in the anti-polishing layer material **507b** and the low-dielectric insulating material **507a** is removed and the film quality is made dense at the same time. At this time, it is required that the plate **40** and the silicon substrate **501** be kept at a temperature of 100 ~ 450°C. An inorganic series material having a dielectric of 2.0 ~ 4.5 is used as the anti-polishing layer material **507b**.

If contraction occurred in the annealing process for making dense the film quality of the low-dielectric insulating material **507a** and the anti-polishing layer material **507b** is not applied vertically to the substrate **501**, between the engraved pattern **41** for forming the trench and the engraved pattern **42** for forming the via hole in the plate **40** and between the low-

dielectric insulating material **507a** and the anti-polishing layer material **507b** are excessively separated, which makes poor the shape of the pattern. In the present invention, therefore, annealing in FIG. 5C and FIG. 5D is implemented for over 10 seconds under an inert gas atmosphere of over 1 atmospheric pressure, so that a pressure of over 1 atmospheric pressure is anisotropically applied vertically to the substrate **501**.

Referring to FIG. 5E, if the plate **40** is separated from the silicon substrate **501**, a multi-layer structure having a plurality of trenches **508** shaped by the engraved patterns **41** for forming the plurality of the trenches formed in the plate **40**, and a plurality of via holes **509** shaped by the engraved patterns **42** for forming the plurality of the via holes formed in the plate **40**, i.e., an insulating film pattern **507** consisting of the low-dielectric insulating film pattern **507a** and the anti-polishing layer material **507b** are fabricated.

By reference to FIG. 5F, an anti-diffusion film **510** and a copper film **511** are sequentially formed on the entire structure of the insulating film pattern **507** including the trenches **508** and the via holes **509**. The copper film **511** and the anti-diffusion film **510** deposited on the insulating film pattern **507** are then removed by a chemical mechanical polishing (CMP) process, so that copper wires **511** surrounded by the anti-diffusion film **510** are formed within the trench **508**. At this time, the copper wires **511** on the via hole **509** are electrically connected to the underlying copper wires **505** by means of the anti-diffusion film **510** and the copper film **511** buried in the via hole **509**. Thereafter, an anti-diffusion film **512** is selectively formed only on the surface of the copper wires **511**.

The anti-diffusion films **504** and **510** are formed in thickness of 0.5 ~ 50 nm by depositing Ta, TaN, TiN, TiNSi, WN, WCN or an alloy of them by means of a physical vapor deposition (PVD), chemical vapor deposition (CVD) or atomic layer deposition (ALD) method.

5 The copper films **505** and **511** are formed by depositing copper (Cu) of 200 ~ 2000 nm in thickness by means of an electroplating, electroless plating or chemical vapor deposition (CVD) method until the trench is completely buried.

10 The anti-diffusion films **506** and **512** formed on the surface of the copper wires **505** and **511** may be formed using a high melting point metal such as W, Ti, Ta, etc., or a compound such as Ni, Co, P, B, etc. The anti-diffusion films **506** and **512** of 1 ~ 100 nm in thickness may be formed only on the surface of the copper wires **505** and **511** by implementing a selective electroless plating method, etc.

15 If the processes of FIG. 5B ~ FIG. 5F are repeatedly implemented, the metal wires of a desired multi-layer structure could be formed.

As described above, a plate for forming metal wires having an engraved pattern for forming a plurality of trenches and an engraved pattern for forming a plurality of via holes is manufactured. An insulating film pattern of a multi-layer structure in which the trenches and the via holes are shaped is
20 obtained by a single process using the plate. Also, a metal is buried into the trenches and the via holes by means of a damascene process, thereby forming upper metal wires electrically connected to lower metal wires.

Therefore, the present invention has new effects that it can prevent

reduction in the yield and reliability due to defects occurring in photolithography and etch processes since the present invention does not employ the photolithography and etch processed, and reduce the production cost and improve the productivity, through reduction of the process steps.

5 Furthermore, if the insulating film pattern is formed using a single material, problems such as low mechanical strength of the insulating film pattern, generation of particles, damage by chemistry, and the like occur in a subsequent metal layer polishing (CMP) process. However, the present invention does not suffer from these conventional problems since the

10 insulating film pattern of a multi-layer structure including the anti-polishing layer is formed.

The forgoing embodiments are merely exemplary and are not to be construed as limiting the present invention. The present teachings can be readily applied to other types of apparatuses. The description of the present

15 invention is intended to be illustrative, and not to limit the scope of the claims. Many alternatives, modifications, and variations will be apparent to those skilled in the art.